

**WHAT IS CLAIMED IS:**

1. A fuel cell system comprising:

a fuel cell stack;

a fuel gas supply unit for supplying fuel gas to the fuel cell stack;

5 an oxidation gas supply unit for supplying oxidation gas to the fuel cell stack;

a fuel cell cooling unit for circulating coolant through the fuel cell stack to cool the fuel cell stack;

a fuel gas humidifier for humidifying fuel gas that is supplied to the fuel cell stack from the fuel gas supply unit by using remaining fuel gas that is exhausted from the fuel cell stack;

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an oxidation gas humidifier for humidifying oxidation gas that is supplied to the fuel cell stack from the oxidation gas supply unit by using remaining oxidation gas that is exhausted from the fuel cell stack; and

a control unit for controlling the fuel gas supply unit, the oxidation gas supply unit, and the fuel cell cooling unit,

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wherein the fuel gas humidifier comprises:

a pair of separating plates that are disposed to face each other such that coolant exhausted from the fuel cell stack flows therebetween; and

a humidifying membrane disposed at a side of the separating plates such that remaining fuel gas exhausted from the fuel cell stack flows on one side of the humidifying membrane and fuel gas that is supplied to the fuel cell stack from the fuel gas supply unit flows on the other side of the humidifying membrane,

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and wherein heat contained in coolant flowing between the pair of separating plates and heat contained in the remaining fuel gas are transmitted to the fuel gas supplied to the fuel cell stack, and water contained in the remaining fuel gas is supplied to the fuel gas supplied to the fuel cell stack through the humidifying membrane.

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2. The fuel cell system of claim 1, wherein the fuel cell cooling unit comprises:

a radiator configured to dissipate heat contained in coolant that has passed through the fuel cell stack;

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a coolant circulating passage connecting the fuel cell stack and the radiator such that coolant circulates through the fuel cell stack and the radiator; and

a coolant pump disposed in the coolant circulating passage and pumping coolant such that coolant cooled by the radiator is supplied to the fuel cell stack and coolant with absorbed heat from the fuel cell stack is supplied to the radiator.

3. The fuel cell system of claim 2, wherein the fuel cell cooling unit further  
5 comprises:

a coolant bypass passage that bypasses the fuel cell stack; and  
a coolant filter disposed in the coolant bypass passage, filtering coolant.

4. The fuel cell system of claim 1, wherein the coolant is an anti-freeze solution.

5. The fuel cell system of claim 1, further comprising an auxiliary humidifier  
10 controlled by the control unit, the auxiliary humidifier collecting water contained in the remaining fuel gas that has passed through the fuel gas humidifier and in the remaining oxidation gas that has passed through the oxidation gas humidifier, and the auxiliary humidifier humidifying the fuel gas that is supplied to the fuel cell stack from the fuel gas supply unit and the oxidation gas that is supplied to the fuel cell stack from the oxidation gas  
15 supply unit.

6. The fuel cell system of claim 5, wherein the auxiliary humidifier comprises:  
a remaining exhaust condensation unit for condensing the remaining fuel gas that has passed through the fuel gas humidifier and the remaining oxidation gas that has passed through the oxidation gas humidifier;

20 a water storage unit for receiving and storing water generated by the remaining exhaust condensation unit;

a first injector for injecting water stored in the water storage unit into the fuel gas supplied to the fuel cell stack from the fuel gas supply unit; and

a second injector for injecting water stored in the water storage unit into the oxidation  
25 gas supplied to the fuel cell stack from the oxidation gas supply unit.

7. The fuel cell system of claim 6, wherein the auxiliary humidifier further comprises an electric heater for heating water stored in the water storage unit.

8. The fuel cell system of claim 7, wherein the electric heater is controlled to operate for a predetermined time if an ambient temperature is lower than a predetermined  
30 temperature.

9. The fuel cell system of claim 6, wherein the first and second injectors are ultrasonic injection nozzles.

10. The fuel cell system of claim 6, wherein the first and second injectors are controlled to operate for a predetermined time after commencing operation of the fuel cell stack.

11. The fuel cell system of claim 6, wherein the remaining exhaust gas condensation unit comprises:

a first condenser condensing the remaining fuel gas that has passed through the fuel gas humidifier;

a second condenser condensing the remaining oxidation gas that has passed through the oxidation gas humidifier;

a radiator cooling a coolant that has passed through the first and second condensers;

a coolant circulating passage connecting the first and second condensers and the radiator such that the coolant circulates through the first and second condensers and the radiator; and

a coolant pump disposed in coolant circulating passage and pumping the coolant such that coolant that has passed through the radiator is supplied to the fuel cell stack, the first and second condensers, and then back to the radiator.

12. A fuel cell system comprising:

a fuel cell stack;

a fuel gas supply unit for supplying fuel gas to the fuel cell stack;

an oxidation gas supply unit for supplying oxidation gas to the fuel cell stack;

a fuel cell cooling unit for circulating coolant through the fuel cell stack to cool the fuel cell stack;

a fuel gas humidifier for humidifying fuel gas that is supplied to the fuel cell stack from the fuel gas supply unit by using remaining fuel gas that is exhausted from the fuel cell stack;

an oxidation gas humidifier for humidifying oxidation gas that is supplied to the fuel cell stack from the oxidation gas supply unit by using remaining oxidation gas that is exhausted from the fuel cell stack; and

a control unit for controlling the fuel gas supply unit, the oxidation gas supply unit, and the fuel cell cooling unit,

wherein the oxidation gas humidifier comprises:

a pair of separating plates that are disposed to face each other such that coolant exhausted from the fuel cell stack flows therebetween; and

5 a humidifying membrane disposed at a side of the separating plates such that remaining oxidation gas exhausted from the fuel cell stack flows on one side of the humidifying membrane and oxidation gas that is supplied to the fuel cell stack from the oxidation gas supply unit flows on the other side of the humidifying membrane,

and wherein heat contained in coolant flowing between the pair of separating plates and heat contained in the remaining oxidation gas are transmitted to the fuel gas  
10 supplied to the fuel cell stack, and water contained in the remaining oxidation gas is supplied to the oxidation gas supplied to the fuel cell stack through the humidifying membrane.

13. The fuel cell system of claim 12, wherein the fuel cell cooling unit comprises:

a radiator configured to dissipate heat contained in coolant that has passed through the fuel cell stack;

15 a coolant circulating passage connecting the fuel cell stack and the radiator such that coolant circulates through the fuel cell stack and the radiator; and

a coolant pump disposed in the coolant circulating passage and pumping coolant such that coolant cooled by the radiator is supplied to the fuel cell stack and coolant with absorbed heat from the fuel cell stack is supplied to the radiator.

20 14. The fuel cell system of claim 13, wherein the fuel cell cooling unit further comprises:

a coolant bypass passage that bypasses the fuel cell stack; and

a coolant filter disposed in the coolant bypass passage, filtering coolant.

25 15. The fuel cell system of claim 12, wherein the coolant is an anti-freeze solution.

16. The fuel cell system of claim 12, further comprising an auxiliary humidifier controlled by the control unit, the auxiliary humidifier collecting water contained in the remaining fuel gas that has passed through the fuel gas humidifier and in the remaining oxidation gas that has passed through the oxidation gas humidifier, and the auxiliary  
30 humidifier humidifying the fuel gas that is supplied to the fuel cell stack from the fuel gas

supply unit and the oxidation gas that is supplied to the fuel cell stack from the oxidation gas supply unit.

17. The fuel cell system of claim 16, wherein the auxiliary humidifier comprises:  
a remaining exhaust condensation unit for condensing the remaining fuel gas that has  
5 passed through the fuel gas humidifier and the remaining oxidation gas that has passed  
through the oxidation gas humidifier;

a water storage unit for receiving and storing water generated by the remaining  
exhaust condensation unit;

a first injector for injecting water stored in the water storage unit into the fuel gas  
10 supplied to the fuel cell stack from the fuel gas supply unit; and

a second injector for injecting water stored in the water storage unit into the oxidation  
gas supplied to the fuel cell stack from the oxidation gas supply unit.

18. The fuel cell system of claim 17, wherein the auxiliary humidifier further  
comprises an electric heater for heating water stored in the water storage unit.

15 19. The fuel cell system of claim 18, wherein the electric heater is controlled to  
operate for a predetermined time if an ambient temperature is lower than a predetermined  
temperature.

20. The fuel cell system of claim 17, wherein the first and second injectors are  
ultrasonic injection nozzles.

20 21. The fuel cell system of claim 17, wherein the first and second injectors are  
controlled to operate for a predetermined time after commencing operation of the fuel cell  
stack.

22. The fuel cell system of claim 17, wherein the remaining exhaust gas  
condensation unit comprises:

25 a first condenser condensing the remaining fuel gas that has passed through the fuel  
gas humidifier;

a second condenser condensing the remaining oxidation gas that has passed through  
the oxidation gas humidifier;

a radiator cooling a coolant that has passed through the first and second condensers;

a coolant circulating passage connecting the first and second condensers and the radiator such that coolant circulates through the first and second condensers and the radiator; and

a coolant pump disposed in the coolant circulating passage and pumping coolant such that coolant that has passed through the radiator is supplied to the fuel cell stack, the first and second condensers, and then back to the radiator.

23. A fuel cell system comprising:

a fuel cell stack;

a fuel gas supply unit for supplying fuel gas to the fuel cell stack;

an oxidation gas supply unit for supplying oxidation gas to the fuel cell stack;

a fuel cell cooling unit for circulating coolant through the fuel cell stack to cool the fuel cell stack;

a fuel gas humidifier for humidifying fuel gas that is supplied to the fuel cell stack from the fuel gas supply unit by using remaining fuel gas that is exhausted from the fuel cell stack;

an oxidation gas humidifier for humidifying oxidation gas that is supplied to the fuel cell stack from the oxidation gas supply unit by using remaining oxidation gas that is exhausted from the fuel cell stack; and

a control unit for controlling the fuel gas supply unit, the oxidation gas supply unit, and the fuel cell cooling unit,

wherein the fuel gas humidifier comprises:

a pair of separating plates that are disposed to face each other such that the coolant exhausted from the fuel cell stack flows therebetween; and

a humidifying membrane disposed at a side of the separating plates such that remaining fuel gas exhausted from the fuel cell stack flows on one side of the humidifying membrane and fuel gas that is supplied to the fuel cell stack from the fuel gas supply unit flows on the other side of the humidifying membrane,

wherein heat contained in coolant flowing between the pair of separating plates and heat contained in the remaining fuel gas are transmitted to the fuel gas supplied to the fuel cell stack, and water contained in the remaining fuel gas is supplied to the fuel gas supplied to the fuel cell stack through the humidifying membrane,

wherein the oxidation gas humidifier comprises:

a pair of separating plates that are disposed to face each other such that coolant exhausted from the fuel cell stack flows therebetween; and

a humidifying membrane disposed at a side of the separating plates such that remaining oxidation gas exhausted from the fuel cell stack flows on one side of the humidifying membrane and oxidation gas that is supplied to the fuel cell stack from the

oxidation gas supply unit flows on the other side of the humidifying membrane, and wherein heat contained in coolant flowing between the pair of separating plates and heat contained in the remaining oxidation gas are transmitted to the fuel gas supplied to the fuel cell stack, and water contained in the remaining oxidation gas is supplied to the oxidation gas supplied to the fuel cell stack through the humidifying membrane.

24. The fuel cell system of claim 23, wherein the fuel cell cooling unit comprises: a radiator configured to dissipate heat contained in the coolant that has passed through the fuel cell stack;

a coolant circulating passage connecting the fuel cell stack and the radiator such that coolant circulates through the fuel cell stack and the radiator; and

a coolant pump disposed in the coolant circulating passage and pumping coolant such that coolant cooled by the radiator is supplied to the fuel cell stack and the coolant with absorbed heat from the fuel cell stack is supplied to the radiator.

25. The fuel cell system of claim 24, wherein the fuel cell cooling unit further comprises:

a coolant bypass passage that bypasses the fuel cell stack; and

a coolant filter disposed in the coolant bypass passage, filtering coolant.

26. The fuel cell system of claim 23, wherein the coolant is an anti-freeze solution.

27. The fuel cell system of claim 23, further comprising an auxiliary humidifier controlled by the control unit, the auxiliary humidifier collecting water contained in the remaining fuel gas that has passed through the fuel gas humidifier and in the remaining oxidation gas that has passed through the oxidation gas humidifier, and the auxiliary humidifier humidifying the fuel gas that is supplied to the fuel cell stack from the fuel gas supply unit and the oxidation gas that is supplied to the fuel cell stack from the oxidation gas supply unit.

28. The fuel cell system of claim 27, wherein the auxiliary humidifier comprises:  
a remaining exhaust condensation unit for condensing the remaining fuel gas that has  
passed through the fuel gas humidifier and the remaining oxidation gas that has passed  
through the oxidation gas humidifier;

5 a water storage unit for receiving and storing water generated by the remaining  
exhaust condensation unit;

a first injector for injecting water stored in the water storage unit into the fuel gas  
supplied to the fuel cell stack from the fuel gas supply unit; and

a second injector for injecting water stored in the water storage unit into the oxidation  
10 gas supplied to the fuel cell stack from the oxidation gas supply unit.

29. The fuel cell system of claim 28, wherein the auxiliary humidifier further  
comprises an electric heater for heating water stored in the water storage unit.

30. The fuel cell system of claim 29, wherein the electric heater is controlled to  
operate for a predetermined time if an ambient temperature is lower than a predetermined  
15 temperature.

31. The fuel cell system of claim 28, wherein the first and second injectors are  
ultrasonic injection nozzles.

32. The fuel cell system of claim 28, wherein the first and second injectors are  
controlled to operate for a predetermined time after commencing operation of the fuel cell  
20 stack.

33. The fuel cell system of claim 28, wherein the remaining exhaust gas  
condensation unit comprises:

a first condenser condensing the remaining fuel gas that has passed through the fuel  
gas humidifier;

25 a second condenser condensing the remaining oxidation gas that has passed through  
the oxidation gas humidifier;

a radiator cooling a coolant that has passed through the first and second condensers;

a coolant circulating passage connecting the first and second condensers and the  
radiator such that coolant circulates through the first and second condensers and the radiator;

30 and



a coolant pump disposed in the coolant circulating passage and pumping coolant such that coolant that has passed through the radiator is supplied to the fuel cell stack, the first and second condensers, and then back to the radiator.